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IMPROVING THE BLACKBOARD

BY

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PREFACE

A little more than six years ago, the National Institute of Industrial Psychology began a series of studies on the working conditions in schools, at the request of various bodies interested. For many years previously the Institute had been investigating conditions in factories and offices with a view to improving the health and well-being of the human factor in industry; and it seemed fairly certain that the experience thus gained and the technique thus acquired would be helpful in the improvement of new school buildings, which the movements of population and other causes were making necessary throughout the country.

The first part of this work on schools consisted of a careful examination of the types of building already in existence and of the conditions which were found in them. Old-fashioned country schools, schools of the central hall type, open-air and semi-open-air schools were examined from the point of view of their general suitability. The investigations included a survey of sickness absences in various types of school and a study of the general standards of heating, ventilation and lighting attained. A brief summary of some of the results of this part of the work has already been published.[1] The next—and probably most valuable—part of the work consisted of the determination by empirical means of the most suitable environmental conditions for children and teachers in school. At the same time, complementary studies were made to ascertain the methods of obtaining the most suitable conditions. These parts of the work are still being continued.

In addition to the considerations of heating, lighting and ventilation, it seemed advisable to give attention to certain essential pieces of school equipment. The first of these to be studied was the blackboard, and the present report contains an account of the work on this subject. In view of the rather striking results obtained, the Institute decided to publish them in a separate report, as the matter seemed of special interest to Local Authorities and to all educationists.

A brief account of the experimental work has already appeared in the *British Journal of Educational Psychology*. The Institute is indebted to the editor, Professor C. W. Valentine, for kind permission to republish it with added details.

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[1] *School Buildings*, by John Sargent and A. H. Seymour, published by the National Union of Teachers, 1932.

This research has been made possible largely through the generous grants received by the Institute from the National Union of Teachers and from the Pilgrim Trust. The Institute wishes also to thank various officers of the Board of Education for their helpful interest.

CHARLES S. MYERS

November, 1937.

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IMPROVING THE BLACKBOARD

I. INTRODUCTION

THIS research was undertaken in the course of a far wider experimental investigation now being conducted by the National Institute of Industrial Psychology into the equipment and environmental conditions relating to school work. The heating and ventilation, the natural and artificial lighting, and the provision of equipment in schools have already received attention, and experiments on these problems are still continuing.

In considering the design of equipment, the blackboard appeared to be the first thing to demand attention. This is an essential part of almost every class and lecture room, and it would seem to share, with the cane, the honour of being the school's most ancient institution.

Certain disadvantages of the blackboard are, however, quite well known. The complaints of teachers, and the strain which was noted, subjectively, in copying from the board, first prompted this investigation. The necessity for some surface on which to record words and plans of temporary and semi-permanent nature is obvious, but often such difficulties in employing the blackboard have prevented its more frequent use.

Before outlining the scope of the present experiments, which were undertaken in an attempt to remove these disadvantages, it is interesting to consider the history of the board. It would appear that scratching with a small piece of slate on a large piece of slate constituted the earliest blackboard writing, which succeeded tracing in sand as a method of public demonstration. Until comparatively recent times pupils wrote in white chalk on a black slate, and the teacher did likewise. This was the habit of the Dame Schools, and it became established in public elementary schools after 1870. More recently—indeed, only since about 1900 in London—children have used white paper to write on, in ink or pencil, and the teacher has retained the white chalk and the blackboard. The importance of this change will be discussed below.

II. PURPOSE OF THE INVESTIGATION

The strain felt by children in copying from the blackboard is well known. It may arise from repeated movements of the head and eyes—especially from changes in accommodation and convergence. It may also be partly due to copying from a *black*board on to *white* paper,

i.e., to the possible alterations, rapid and continually reversed, in the level of adaptation[1] of the eye. Ordinary white paper has a reflexion factor[2] of about 85 per cent., a blackboard of about 10-15 per cent.

The following experimental work was carried out, therefore, to determine whether a board with higher reflexion factor would enable children to copy more quickly and with less strain, and remove some of the disadvantages inherent in the usual board.

III. PREVIOUS WORK

As far as can be ascertained, no experimental work on this subject has been done. Boards other than black have been used in schools—green boards are not uncommon—but their selection has been, apparently, on aesthetic rather than on physiological grounds.

Writers on classroom equipment have usually accepted the blackboard as an inevitable and unalterable part of the teaching apparatus. Félix Narjoux, in his work *Les Ecoles Publiques en France et en Angleterre* (Paris, 1877) gives this picture of the blackboard:—

" Ce tableau mobile est formé d'une grande ardoise encadrée dans des traverses de chêne. Il se place en avant des élèves, dans la partie de la classe restée libre, et sert aux explications du maître."

The subject, thus concisely epitomized, is usually dismissed even more scantily by other writers. Felix Clay in his *School Buildings* (1902) quotes Zivey (*Schulhygiene*, 1898) as to the distance at which a blackboard may be read, but makes no comment on colour, size or type.

The influence of colour on legibility has received considerable attention. Luckiesh[3] quotes *Le Courier du Livre* as stating that black lettering on a yellow ground is the most legible combination. Also from

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[1] We ought perhaps to distinguish brief or immediate adaptation from prolonged and progressive adaptation. The former perhaps should be ascribed rather to the immediate interaction between retino-cerebral elements than to dark adaptation in the more familiar sense. Thus D. Katz (*The World of Colour*, p. 177) states "We must make a sharp distinction between such instantaneous adaptation and durative adaptation, since the two types of adaptation have entirely different causes and also significantly different effects ", and quotes Hering (*Zur Lehre vom Lichtsinn*). See also Appendix.

[2] The proportion of the light reflected by, to the light falling upon, a surface is known as the reflexion factor. This is normally expressed as a percentage.

[3] M. Luckiesh. *Colour and its Applications*. New York, 1927.

his own experiments he says that "these data indicate an advantage in defining power of monochromatic[1] yellow light over other monochromatic lights of equal brightness."

American psychologists have recently carried out tests on the legibility of various colour contrasts. Tinker[2] obtained results slightly different from those quoted by Luckiesh, and found black on a yellow ground, while easily legible, to be surpassed by black, blue or green on a white ground. Another investigator, F. C. Summer[3] of Howard University, has studied the legibility of various colour combinations at a distance, and finds black on yellow third in order, after blue on grey and black on grey. It is generally agreed by these writers that legibility depends on the difference between the brightness of the lettering and that of the background.

The black-white contrasts have also been studied in some detail. C. D. Taylor[4] found that white letters on a black background were definitely less legible than black letters on white. Another worker, G. Holmes,[5] also found a marked difference, amounting to 14·7 per cent., in favour of black print on a white ground as compared with white print on a black ground.

The problems of type and legibility have received considerable attention. The influence of size on legibility has been investigated by Pyke[6] and by Hovde.[7] Tinker and Paterson[8] found no important difference in the rate of reading text material with any of the ordinary type

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[1] This does not apply except for *monochromatic* yellow light. The light reflected from an ordinary yellow surface includes the whole spectral band from yellow to red, and is anything but monochromatic.

[2] M. Tinker and D. Paterson. "Studies of the Typographical factors influencing speed of reading. VII, Variations in Colour of Print and Background." *J. App. Psychol.* XV, 1931.

[3] F. C. Summer. "Influence of Colour on Legibility of Print." *J. App. Psychol.* XVI, 1932.

[4] C. D. Taylor. "Relative Legibility of Black and White Print." *J. Educ. Psychol.* Vol. XXV, 1934.

[5] G. Holmes. "Relative Legibility of Black Print and White Print." *J. App. Psychol.* XV, 1931.

[6] R. L. Pyke. *The Legibility of Print.* Med. Res. Council, 1926.

[7] H. T. Hovde. "The Relative Effects of Size of Type, Leading and Context." *J. App. Psychol.* XIII, 1929.

[8] M. Tinker and D. Paterson. "Studies of the Typographical factors influencing speed of reading. X, Style of Type Face." *J. App. Psychol.* XVI, 1932.

faces. In England, work on reading, and on the typographical factors influencing legibility, has been done by M. D. Vernon.[1]

It will be noted that none of these studies deals with the especial problem of the present work—namely the difference between ability to read when the subject is repeatedly changing from white letters on a black ground to black letters on a white ground, and when the letters and ground are unchanged in brightness. These studies have, however, been of great value in enabling a selection to be made of all the various possibilities that might have been investigated. They indicate, for instance, that black letters on a white ground are more easily read[2] than white letters on a black ground; and that black letters on a yellow ground constitute one of the most useful combinations. These results enabled the field of the present investigation to be narrowed considerably.

The brightness difference between letters and background constitutes probably the major factor in determining the ease of reading, but subjective psychological factors cannot be dismissed as having no influence. Various workers have noted (for example Summer and Hovde, *op. cit.*) the 'stimulating' effect of certain colours; others have found that print of the customary size, shape, etc., is preferred by readers to unusual print, and is read more easily.

IV. CONSIDERATIONS INVOLVED

A study of the use of the blackboard showed that its main purpose is twofold. It is used :—

(*a*) For purposes of demonstration, for the drawing of figures, plans, maps, etc., and for writing difficult words and important sentences.

(*b*) As a surface from which others may copy. In this case the subject matter, similar to that in (*a*) above, is copied on to another surface (usually on to white paper) by the individual student.

In some schools surfaces of paper (often light in colour) are used in preference to the blackboard for semi-permanent display of subject matter under (*a*) above. Display of all kinds is widely used in modern classroom teaching, and has led frequently to the provision of blackboards or display-boards all round the room.

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[1] M. D. Vernon. *An experimental study of reading.* Cambridge, 1931.

[2] Not necessarily, of course, copied.

When the blackboard is being used for the purpose (*a*) above, the visual task is not usually very difficult. Under classroom conditions the board is placed at a distance of between 5 and 20 feet ; the writing is usually in letters about one inch high, and plans and diagrams may be drawn (in white or coloured chalks) to a suitable size. Under these conditions, and when the level of illumination on the board is adequate, normal-sighted persons can read without great difficulty ; the eyes are accommodated for a fixed distance and with the correct degree of convergence, and are adapted to the illumination throughout the general field of vision.

When, however, the blackboard is used as a surface from which to copy, the problem is very different. Even when the illumination is adequate on both planes, the difficulties of discrimination are increased by their brightness differences. The eye, looking, for instance, at a white paper, adapts itself to that brightness, which is high owing to the high reflexion factor.

But on looking up to the board—which may subtend roughly the same visual angle—the pupil and retina need to readapt themselves[1] to a much lower brightness, due to the lower reflexion factor. The blackboard is frequently in such a position that the illumination on it is less than on the horizontally placed paper, with the result that the brightness difference is further increased. At the same time changes in accommodation and convergence are required.

The strain resulting from copying from the blackboard apparently prevents teachers from using more often this useful educational aid. It seemed impracticable to reduce the changes in accommodation and convergence required in the act of copying, but there appeared to be scope for reducing the pupillary and retinal adaptation. It was hoped by this means to reduce the time necessary for copying, and the strain involved in it.

Scope of the Experiments

It seemed advisable, therefore, to experiment with the use of a board displaying dark letters on a light ground whose brightness should

[1] It cannot, of course, be said that the eye adapts itself to the brightness of objects occupying the central parts of the retina only. Although this is the most important factor it would seem that the brightness of objects seen by non-central parts of the retina plays an important part in adjusting the whole retina including the fovea to the correct level of adaptation.

approximate to that of the white paper on which the copying was done. The use of such a board would necessitate the same changes in accommodation and convergence, but would require less adaptation.

The choice of colour of surface for experimental purposes presented some difficulties. White was ruled out as likely to give rise to glare, and to a disagreeable psychological effect.

Of the colours available, few would provide a sufficiently high reflexion factor to be considered comparable with that of white paper (approximately 85 per cent.). In this respect coloured boards previously used—such as green—are only slightly higher than black.

It was finally decided, as a result of these considerations and of the findings of other investigators mentioned in section III, to experiment with a light yellow or primrose board, a little lighter than British Standard Colour No. 54.[1] This combined the advantages of a high reflexion factor and of a colour found by many subjects to be agreeable and stimulating.

For use on this board, as a result of a short test on a dozen subjects, dark-blue letters were found to be more easily read than black, although at normal blackboard distance they were indistinguishable in colour from black.

Before comparing the results obtained on the experimental board with those on a blackboard, a study was made of the changes in the pupil size when looking at different coloured surfaces. This is dealt with under "Considerations of Pupil Size" below.

The experimental work in comparing dark-blue lettering on the yellow experimental board with white lettering on a standard blackboard was done in two series of experiments. One part was laboratory work, in which adult subjects were tested; the other consisted of field experiments with children as subjects in their ordinary class-rooms. These are dealt with under "Laboratory Experiment" and "Class-room Experiments" below.

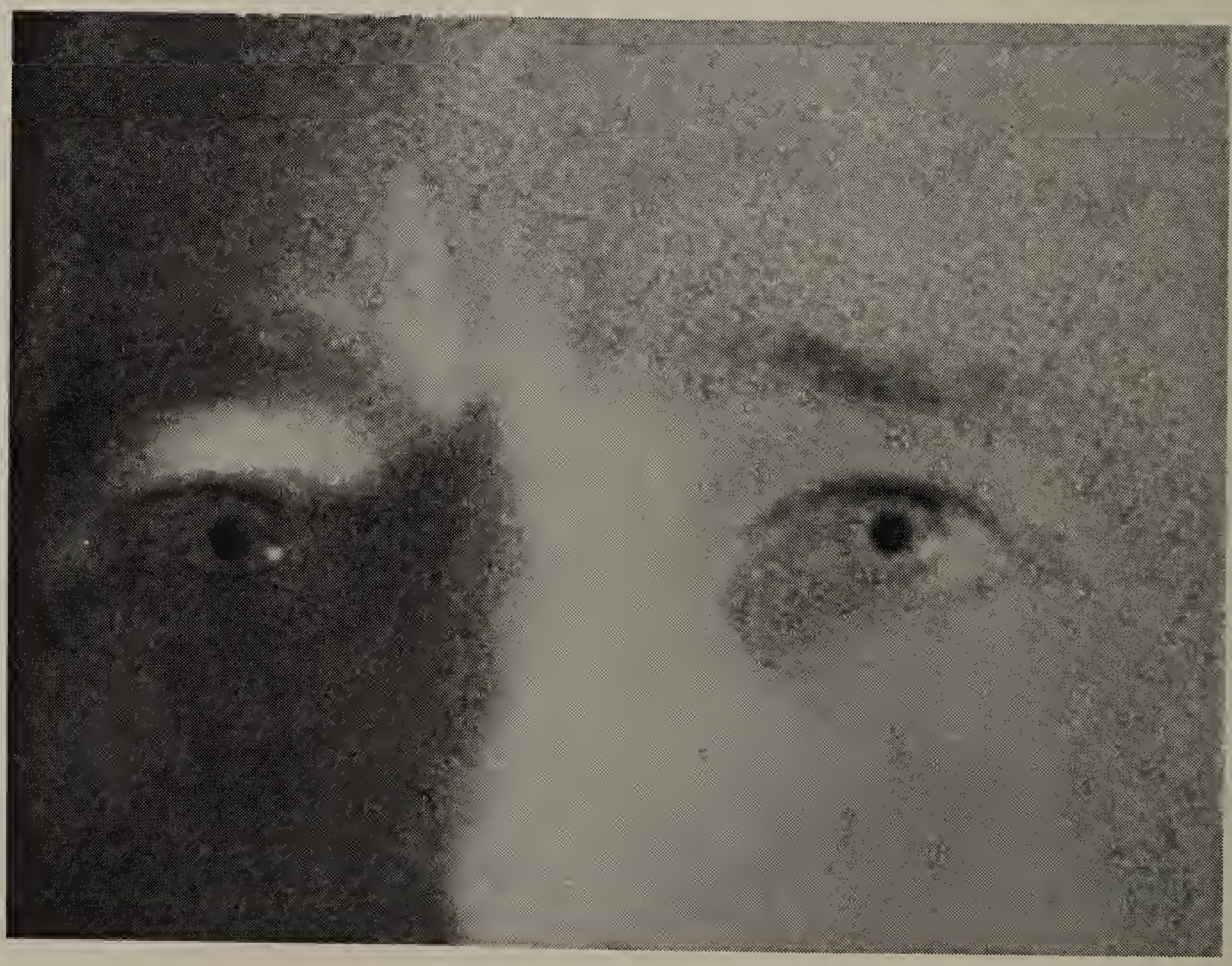
V. CONSIDERATIONS OF PUPIL SIZE

In order to determine the pupil changes involved in glancing from white paper to blackboard, measurements were made of a pupil when regarding a black surface and when regarding a white surface with the

[1] Further details are given in section IX.

FIG. I.

Photograph of Pupil of the Eye Looking at a White Surface.



Photograph of the same Pupil Looking at a Black Surface with the same Illumination.

To face page 15

same illumination. This was done by placing first a white screen 2 feet square at a distance of 3 feet (*i.e.* to subtend a visual angle similar to that subtended by a child's paper or a blackboard) from the subject's eye, which was then photographed. The experiment was then repeated with a black screen. Despite the fact that the illumination of each screen was the same, the difference in pupil size, as measured on the photographs (Fig. I) with the aid of dividers, amounted to nearly 20 per cent.

While this part of the experiment was being carried out, it was found that similar work was being done (for a different purpose) at the National Physical Laboratory with the far greater resources of its Photometric Laboratory. The results[1] obtained there were kindly put at the disposal of the present writer.

B. H. Crawford, who was responsible for this work, measured the variations in pupil size of ten subjects when subjected to fields of different brightnesses and subtending an angle of approximately 60 degrees. Large variations of brightness were used and wide individual differences were found. Within the range of brightness difference produced by a blackboard and white paper with the same illumination, the difference of pupil size was quite marked ; in the first case the mean pupil diameter of ten subjects was 4.48 mm., in the second the corresponding figure was 3.87—a difference of .61 mm. or 16 per cent. The pupil sizes quoted are those likely to result from the difference between the reflexion factors of blackboard and white paper under the ordinary conditions of classroom lighting. It may be noted that other workers (Lythgoe,[2] Reeves,[3] and Holladay,[4]) found even greater differences.

These changes in pupil size are unlikely in themselves to constitute a source of strain. The time taken for such a change is quite considerable but, as can be easily demonstrated, visual discrimination is possible before the pupillary adaptation is complete. It is rather the concurrent retinal adaptation which may be considered the more serious problem, and a reduction in this would doubtless have beneficial results in the saving of time and in the reduction of fatigue. The problem of this change of visual state must be approached by considering the

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[1] Subsequently published as "The Dependence of Pupil Size upon External Light Stimulus under Static and Variable Conditions". *Proc. Roy. Soc.*, B. No. 823, Vol. 121.

[2] K. J. Lythgoe. Report Med. Res. Council. X. "Measurement of Visual Acuity."

[3] P. J. Reeves. *Opt. Soc. Amer.* Vol. 4.

[4] L. J. Holladay. *Opt. Soc. Amer.* Vol. 12.

chemical and neural changes determining visual sensitivity. As Crawford points out, "when the eye is viewing some given external distribution of brightness, the concentration of photo-chemical substances in the various parts of the retina, the nervous messages sent from retina to brain and the consequent reactions in the latter will all be tending towards certain equilibrium values. When the external brightness distribution is changed, these equilibrium values will also change in the direction of a new set of equilibria."[1]

VI. LABORATORY EXPERIMENT

General Experimental Conditions

The aim of this experiment was to measure under laboratory conditions the difference between the time taken by subjects to read nonsense syllables on a yellow board and on a blackboard, after they had been fixating the centre of a white area.

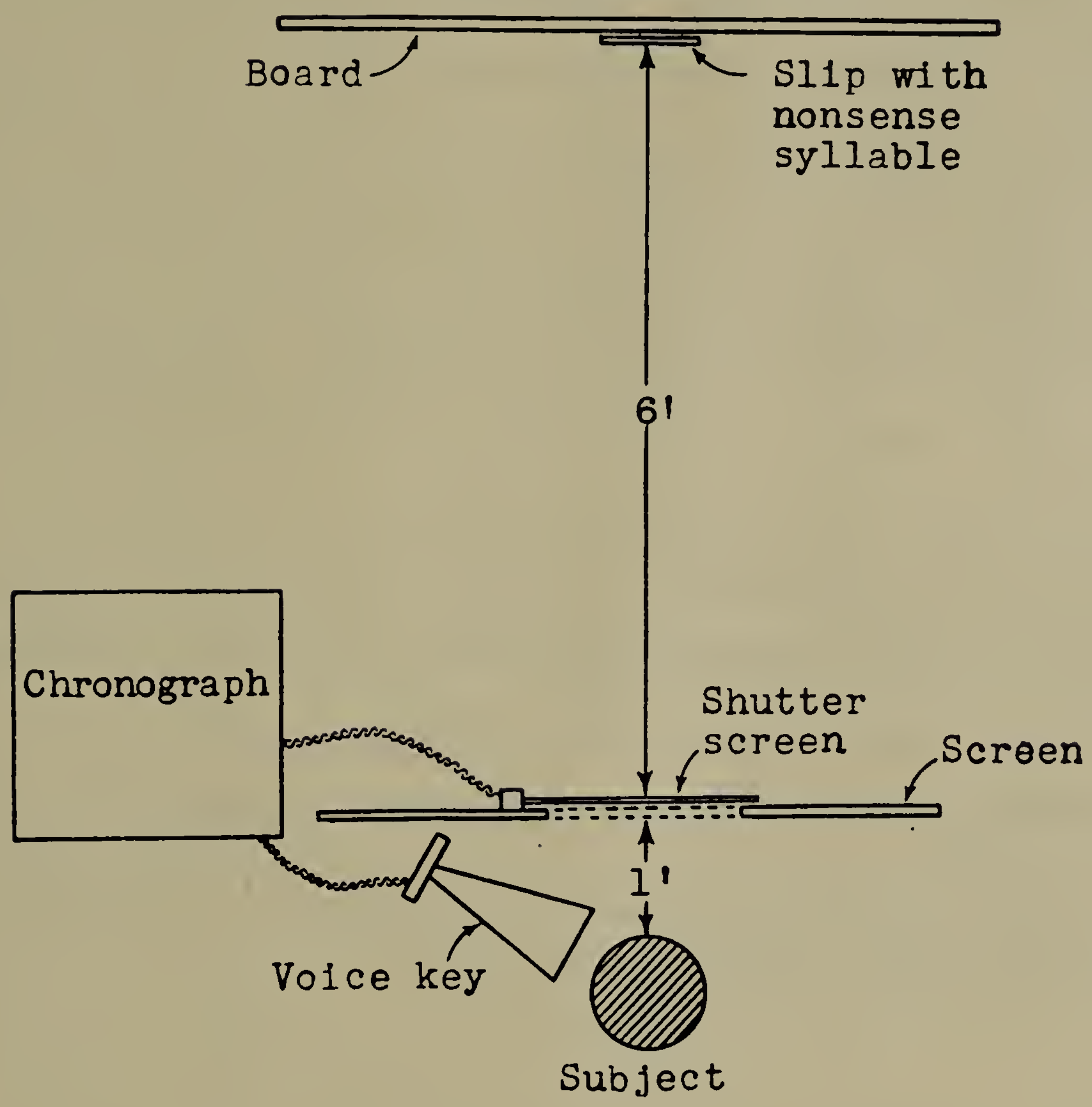
The subject sat in front of a large neutral-coloured screen, in the centre of which was a smaller white screen representing the pages of a copy-book. The experimental conditions necessitated that this should be on the vertical instead of the horizontal plane. At intervals the white screen opened, exposing a board on which was exhibited a test word, and the time taken for the subject to say the word was measured. After initial practice the subjects were given a series of ten test words written in dark blue on a yellow board, followed by a longer series of twenty in white letters on a blackboard, and then by another series of ten on the yellow board. The order of presentation of the boards was reversed for each succeeding subject (*i.e.* one had Y.B.Y. ; the next B.Y.B.).

The experiments were done in daylight, with the subject facing away from the window which had a north aspect. The illumination on the white screen was two-and-a-half times that on the board—conditions which are fairly representative of those found in classrooms. The subject's eyes were approximately 12 inches from the white screen and 7 feet from the board.[2] The blackboard had a reflexion factor of 14 per cent., and the writing thereon of 80 per cent.; the reflexion factor of the yellow board was 85 per cent., and that of the dark lettering 15 per cent.

[1] B. H. Crawford, " Change of Visual Sensitivity with Time." *Proc. Roy. Soc.* B. No. 830. Vol. 123.

[2] Except in two cases mentioned below.

DIAGRAM OF APPARATUS



Apparatus

The boards were the same as those used in the classroom experiments (section IX below). The test words consisted of nonsense syllables each of which contained three letters and commenced with a stop consonant followed by a vowel in order to ensure a positive action from the voice key. The letters were made with half-inch Unique stencils—that is to say, of half the normal size, owing to the fact that the boards were at approximately half the normal classroom distance.

The apparatus occupied practically the whole field of vision, both with the screen open and shut. The neutral coloured board was about three feet square, and centrally placed within it was an aperture nine inches square covered with a double shutter of white cardboard, containing a central spot for the subject to fixate. The two halves of the

shutter were hinged like doors, and opened rapidly away from the subject when a spring was released, so that there was no tendency for the subject's eyes to be carried away from the centre of the aperture by the movement of the fixation spot. The speed of response was timed by a pen track on a paper tape ; a motor, controlled by an electrically maintained vibrating reed, advanced this tape at constant speed. The magnet coils actuating the pen were wired in series with a switch attached to the shutter and with a contact actuated by a voice key. This circuit was closed when the shutter reached the fully open position and was broken when the subject's voice actuated the voice key.[1] The latter was of the type where the sound is concentrated on to a microphone by means of a short trumpet ; it was sensitive enough to be actuated by a normal speaking voice when the mouth of the trumpet was well to one side and none of it in the subject's field of vision. A test of the time lag of the apparatus was made by arranging that the shutter on reaching the fully open position made a sound loud enough to operate the voice key. Numerous trials were made and the probable error of the mean of the time lag was determined. This was found to be negligible in comparison with the variation and probable error in the times of the subjects' responses. The mean time lag of the apparatus was subtracted from the recorded times of the subjects' responses.

Method

The subject sat facing the screen, with his mouth near to the trumpet of the voice key, and fixated the spot in the middle of the white square. It was explained that the white screen would open and that he was required to read aloud, as soon as he was able, the nonsense syllable which was on the board behind. Half a dozen trials were given before the reading times were recorded. The subjects had about five minutes for preliminary adaptation to the white screen, and about half a minute for adaptation between the shutting and the re-opening of the shutter screen. Each subject read twenty nonsense syllables from each board.

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[1] The entire apparatus was constructed at the National Institute of Industrial Psychology by Mr. D. F. Vincent, B.Sc., who also kindly assisted in conducting the experiment.

Subjects

It was found advisable, owing to the complexity and delicacy of the apparatus, to use adult subjects. They were of both sexes, and had presumably normal, or at all events approximately normal, sight, except in five cases whose results are discussed separately below. Three-quarters of the subjects were in the twenty to thirty year age group. The ultimate purpose of the experiment was not explained until after its completion, although several of the subjects then admitted that they had perceived its aim. No data have been omitted except those obtained in experimental runs to test the apparatus.

Results

The results shown on page 20 were obtained. (The subjects with known refractive defects are starred ; two subjects to whom the boards were illegible at 7 feet were tested with the boards at 4 feet 6 inches.)

VII. DISCUSSION OF RESULTS

It will be seen that each of the twenty-two subjects tested was able to read more rapidly from the yellow than from the blackboard. The results considered as a whole are statistically significant, and it is worth noting that in the case of Nos. 13 and 14 above—with the greatest P.E. —the difference between the medians and between the inter-quartile ranges is similar to that between the means.

The subjects were asked to record their subjective impressions. Several said that they found the yellow easier to read ; No. 12 was doubtful whether he was any quicker on it ; Nos. 6 and 21 found the yellow very definitely easier to read. No. 8 was troubled, after looking at the blackboard, by positive and negative after-images on the white screen ; when using the yellow board positive after-images were noted. No. 13 noted a difficulty in fixating the writing on the blackboard—the letters appeared to revolve in circles before they could be read. The letters on the yellow board did not appear to move.[1]

An analysis of the results indicates scope for further experiment. The average difference between the results on the black and yellow boards was 15.4 per cent.

[1] The investigator noted this also when himself doing the test. His score (which is naturally omitted in the above list) amounted to the significant difference of 24 per cent. in favour of the yellow.

Table I Reading Times

Subject		*Mean Time in Seconds*	*Difference*	*P.E. of Difference*	*Percentage Difference*
1*†	Black	.703	.082	.014	13
	Yellow	.621			
2*	Black	.676	.136	.019	25
	Yellow	.540			
3	Black	.649	.104	.015	19
	Yellow	.545			
4	Black	.703	.027	.019	5
	Yellow	.676			
5	Black	.676	.060	.017	10
	Yellow	.616			
6*†	Black	.438	.119	.013	37
	Yellow	.319			
7	Black	.590	.076	.020	15
	Yellow	.514			
8	Black	.665	.092	.015	16
	Yellow	.573			
9*	Black	.730	.120	.013	19
	Yellow	.610			
10	Black	.643	.033	.012	5
	Yellow	.610			
11	Black	.568	.065	.015	13
	Yellow	.503			
12	Black	.422	.071	.014	20
	Yellow	.351			
13	Black	.762	.070	.024	10
	Yellow	.692			
14	Black	.584	.098	.027	20
	Yellow	.486			
15	Black	.508	.059	.021	14
	Yellow	.449			
16	Black	.698	.055	.019	8
	Yellow	.643			
17	Black	.432	.054	.018	14
	Yellow	.378			
18	Black	.698	.066	.019	10
	Yellow	.632			
19	Black	.806	.054	.019	7
	Yellow	.752			
20	Black	.459	.072	.017	18
	Yellow	.387			
21*	Black	.816	.140	.023	21
	Yellow	.676			
22	Black	.730	.054	.014	8
	Yellow	.676			
				Mean	15.4 per cent.

*These subjects were known to have refractive defects. †For these subjects, owing to their defective vision, the boards were placed at the shorter distance of $4\frac{1}{2}$ feet.

The average for the five cases with known refractive[1] defects was 23.1 per cent. ; that for the rest 12.9 per cent. The numbers are insufficient to form the basis of any conclusions in regard to this difference, but the investigator hopes to be able to examine the point by means of other experiments. Both from the social, and from the educational, point of view, it would be particularly advantageous to ameliorate conditions for those suffering from refractive defects.

Apparent Size

A subjective impression, not properly part of the experiment, was noted by subjects who did this experiment, and by others who saw the apparatus for the classroom experiments. When the yellow and the black boards were seen side by side, the writing on the former seemed larger to a considerable number of people.

This phenomenon, casually discovered, seemed worthy of further investigation. It would appear doubtful whether it was the cause of the improvement, since—

(*a*) The apparent difference in size was only noticed when the two sets of writing were side by side[2] (which did not occur during any of the experiments) ;

(*b*) Other workers on legibility (section III above) have found that a large change in size is necessary before any difference in ability to read is noticeable.

At first sight this phenomenon appeared to be in direct contradiction to the usual observation of irradiation. A further study, however, showed that this was not the case. Solid circles and ring circles were drawn in white and dark blue on the black and yellow boards respectively. Four subjects were asked which appeared larger, and they found the solid white circle to be larger than the solid dark blue one, but the ring circle on the yellow board appeared larger than that on the black board.

This result agrees with an explanation suggested by the investigator of a phenomenon met with not only here, but by others working on the same problems. White letters on a black ground appear smaller (and

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[1] The information available regarding the eyesight of these subjects was insufficient to warrant any conclusive deductions.

[2] The writing on the yellow board may, however, produce a better retinal image. See Appendix.

not, as might be expected, larger) than dark letters on a light ground, owing to the fact that there is a tendency to regard the enclosed space within letters, rather than their outside shape. An analysis of the alphabet shows that all letters except f, i, j, l, t are enclosed (like o) or semi-enclosed (like c). The preponderating majority of enclosed and semi-enclosed letters, and a tendency to regard spaces rather than outside configurations, may possibly explain this phenomenon.

VIII. REVERSED EXPERIMENT

Table 1a Reading Times

Subject		*Mean Time in Seconds*	*Difference*	*P.E. of Difference*	*Percentage Difference*
7	Black	.524	.086	.019	16
	Yellow	.610			
8	Black	.562	.017	.017	3
	Yellow	.579			
9	Black	.411	.054	.011	13
	Yellow	.465			
10	Black	.389	.049	.011	13
	Yellow	.438			
11	Black	.486	.054	.020	11
	Yellow	.540			
12	Black	.362	.033	.013	9
	Yellow	.395			
14	Black	.340	.055	.018	15
	Yellow	.395			
15	Black	.400	.038	.013	10
	Yellow	.438			
16	Black	.518	.061	.016	12
	Yellow	.579			
17	Black	.405	.038	.012	9
	Yellow	.443			
18	Black	.626	.018	.011	3
	Yellow	.644			
19	Black	.637	.039	.014	6
	Yellow	.676			
22	Black	.746	.027	.013	4
	Yellow	.773			
				Average Percentage	9.5

Subsequently, the experiment described above was repeated but with the conditions reversed. That is to say the subject sat facing a black

screen (of the same size as the small one used previously) and the illumination falling upon the board was arranged to be two-and-a-half times that falling upon the screen. It was found more convenient to use artificial light, the intensity on the board being 30 f.c., that on the screen being 12 f.c.

Exactly the same method and the same subjects were used. It was not, however, possible for all the subjects to do the test again, with the result that the group was reduced from twenty-two to thirteen.

As might be expected the subjects were now able to read more rapidly from the blackboard, and the actual results are given in Table 1*a*. Several of the subjects stated that they were able to read the blackboard more easily, and although some of the results are not statistically significant, they may be regarded as tending to support the deductions drawn from the results of the other experiment, namely that the difference in time between reading from the black and from the yellow board was due to the adaptation of the eye in changing from a white screen to the blackboard or from a black screen to the yellow board.

IX. CLASSROOM EXPERIMENTS

The object of this series of experiments was to compare the speed of the process of copying by children, according as they copied from white letters on a blackboard or from dark letters on a light-coloured board. The conditions were so arranged as to approximate, as nearly as possible, to those of ordinary classwork.

The subjects were children attending four elementary schools in Barking and Ealing. One of these schools was a senior school, where three younger classes, consisting of boys and girls aged from 11+ to 12+, were tested. The others, junior schools, had the advantage of affording an unselected group of children, but the results obtained in the senior school agreed closely with those obtained in the junior schools.

Of the two boards used one was a standard blackboard, measuring 3 feet by 2 feet, and framed in $1\frac{3}{4}$ inch light oak, such as is usually supplied to elementary schools. The other board, identical in size but framed in darker oak, was yellow, a little lighter than primrose (British Standard Colour No. 54). The letters on the blackboard were

written in white ink, and on the yellow board in ink of a very deep-blue colour. The reflexion factors for the black and yellow boards were 14 and 85 per cent. respectively, and for the white and deep-blue inks 80 and 15 per cent. respectively. The letters were stencilled on to each board by the same one-inch stencil and by the same No. 7 pen. They were equally spaced on each board.

The test-passage was carefully chosen so that it should be comprehensible to children aged eight and nine and yet be interesting to those aged eleven and twelve. It consisted of 100 words (396 letters) and was as follows—

> " When the ship sank, Captain Smith swam 10 miles to the island. All the rest of the crew were drowned. At first, the island seemed deserted. Captain Smith dragged himself 20 yards along the beach and went to sleep in the shade of an oak tree. When he woke up, there was a little noise behind his head. He looked round and there, sitting 5 yards behind him, was the little man with the magic wand. The little man waved his wand 3 times. 'What do you want?' he asked. The Captain sprang up. 'It's you I want,' he cried."

It was thought better to use several experimental methods rather than to test a larger number of children by one and the same method. Three methods were adopted, none of which, however, was entirely free from criticism. But as the results of each of them pointed definitely in the same direction, they may be considered to be more reliable than if they had been derived from a single experimental method.

All the tests were given by the investigator himself to children in the presence of their teacher and in their usual classrooms, save in one school in which the children, however, were accustomed to move from one classroom to another. The teacher gave no indication of the nature of the test ; he merely instructed the children to head their papers with their name, age, etc., and informed them that they were about to have a 'do as you are told' lesson.

The investigator told the children that he wanted them to copy from some boards that he had brought with him. " I am going," he said, " to put a board on the easel. First of all I want you to read it right through from beginning to end. When you've read it, I shall say

'Are you ready?', and then, when I say 'Off you go!' I want you to copy it down on to your paper."[1]

The experiments were timed by a stop watch. Each letter and numeral copied scored one point. No points were given for punctuation, nor did errors in punctuation, spelling, etc., receive any penalty.

All the results obtained are recorded, with the following omissions in the third part (*i.e.* Method 3) of the experiment :—

1. Any child recommencing in the second period was disqualified, but those starting again in the third period were not disqualified.

2. At the beginning of the experiment the time necessary was not correctly estimated, with the result that almost the whole of one class started again in the second period. This class was ruled out as a "preliminary run".

3. Groups of twelve and less in Method 3 (*a*) were omitted as explained below.

Method 1

A group of over 100 children, aged between 11+ and 12+, copied for a fixed period (six or eight minutes according to age) from the blackboard ; and another group of the same age and approximately of equal size, strictly comparable in educational attainments, copied from the yellow board for the same length of time. The results are shown in Table 2.

TABLE 2

Number of children	*Colour of board*	*Mean no. of letters copied per minute*	*Difference and its P.E.*	*Percentage increase for yellow board over blackboard*
115	Black	32.3	3.2±0.85	9.9
107	Yellow	35.5		

From this table it will be seen that the group which copied from the yellow board copied on the average nearly 10 per cent. more letters than

[1] The brightness of the children's individual papers was not measured, nor was the illumination on their individual desks. It may be assumed, however, from measurements taken later that the illumination on the papers was in practically every case greater than that on the boards. The surrounding conditions, both in relation to the papers and the boards, were of course identical when copying from the black and from the yellow board.

the group which copied from the blackboard, and that this difference is statistically significant, being nearly four times its probable error.

Method 2

In this experiment, one group of nearly 200 children, aged between 10 and 12, copied the passage from the blackboard as far as they could, and then (starting afresh) copied the same passage from the yellow board for the same period of time as in the previous experiment. A second and strictly comparable group started on the yellow board and changed to the blackboard. Each group, owing to increasing familiarity with the passage, copied more from the second board than from the first. The results are shown in Table 3.

Table 3

Number of children	*Colour of first board*	*Colour of second board*	*Mean number of letters copied from black-board*	*yellow board*	*Difference*	*Percentage difference*
192	Yellow	Black				
			32.80	35.27	2.47	7.55
194	Black	Yellow				

It will be seen that the mean number of letters copied per minute from the yellow board (first and second attempts) is 2.47 greater than the mean number copied per minute from the standard blackboard—that is, a difference of over 7.5 per cent. in favour of the yellow. Obviously the experimental conditions do not permit of the above data being treated for the evaluation of probable errors.

Method 3

Here over 400 children, aged between 8 and 11, copied continuously first from the black, next from the yellow, and finally from the blackboard. The total time spent on copying from the blackboard was the same as that spent in copying from the yellow board. The youngest children, aged 8+, were given 4, 8 and 4 minutes, those aged 9 and 10 were given 3, 6 and 3 minutes, and those aged 11 were given $2\frac{1}{2}$, 5 and $2\frac{1}{2}$ minutes, for these three periods respectively. In this experiment they were instructed to go straight on with the passage from one period to another and to start again at the beginning of the third period if they had come to the end of the passage.

The results are shown in Table 4. It was thought interesting here to arrange them in relation to speed of copying. The three groups of differently aged children are accordingly each sub-divided on the basis of the number of letters which they were able to copy from the blackboard. It is clear that, whether the children are fast or slow copiers, the percentage increase in copying from the yellow board, as compared with the amount copied from the blackboard, is approximately the same. The differences range from nearly three to eight times their probable errors.

In this large group of 402 children there were 91 who failed to copy more from the yellow board than from the blackboard. A certain number of these exceptional cases may be attributed to such accidental disturbances during the experiment as dropping the pen, blowing the nose, etc., which were, in fact, observed to occur by the investigator and to favour the exceptional results obtained. This, however, is unlikely to account for more than about one-quarter of the 22.6 per cent. of exceptional children. Perhaps in some cases the yellow board may

TABLE 4

Time in Minutes	*Range of number of letters copied from blackboard*	*Number of children*	*Mean number of letters copied from black-board*	*Mean number of letters copied from yellow board*	*Difference and its P.E.*	*Percentage increase for yellow board over blackboard*
$2\frac{1}{2}$, 5 and $2\frac{1}{2}$	125–150	25	137.5	150.0	12.5 ± 2.42	9.2
	150–175	27	153.2	178.9	15.7 ± 3.20	9.6
3, 6 and 3	50–75	23	64.0	70.4	6.4 ± 1.90	10.0
	75–100	54	88.3	96.3	8.0 ± 1.92	9.0
	100–125	77	110.5	122.2	11.7 ± 1.75	10.5
	125–150	62	137.7	149.7	12.0 ± 2.27	8.7
	150–175	59	161.7	174.6	12.9 ± 2.10	8.3
	175–200	29	183.5	200.7	17.2 ± 2.86	9.1
	200–225	15	208.3	228.7	20.4 ± 3.45	9.5
4, 8 and 4	100–150	14	127.4	158.7	31.3 ± 5.44	24.6
	150–200	17	169.9	183.1	13.2 ± 4.70	7.8

have suffered adversely through its strangeness, and in some others through the dislike of its colour.[1] In others, again, the disadvantages

[1] There is, on the other hand, the possibility that the speedier copying from the yellow board in the majority (77.4 per cent.) of the children was partly due to the stimulus of its novelty. But this explanation cannot be applied to the shorter reading times of the adults (Section VI).

of the blackboard may have been compensated for by increased effort. But it is clear that these exceptional cases demand future closer investigation.

The same children who undertook the previous experiment repeated it later, but this time the blackboard was used in the middle period.[1] Unfortunately, owing to the approach of the summer vacation, only a week elapsed between the two experiments, and this proved insufficient for the children to have forgotten the passage. Consequently they copied considerably more in the same time, some of them being observed to write quite long passages without reference to the board. It is not surprising, then, that the results recorded in Table 5 show a great reduction in the advantage of the yellow board.

TABLE 5

Time in minutes	*Number of Children*	*Mean number of letters copied from blackboard*	*from yellow board*	*Difference*	*Percentage increase for yellow board over blackboard*
$2\frac{1}{2}$, 5, $2\frac{1}{2}$	67	196.0	200.4	4.4	2.3
3, 6, 3	304	170.0	172.6	2.6	1.5
4, 8, 4	37	181.8	184.0	2.2	1.2

The differences are not statistically significant. But they support the strikingly significant results of the three previous experiments on schoolchildren and those of the reading times of adults.

The Children's Choice

The children doing the above test were asked at the end to write down the colour of the board they preferred with reasons if possible.

Of the total 419 children 268 (64 per cent.) preferred the yellow, 151 (36 per cent.) preferred the blackboard. The reasons given were various[2] :—

165 (39.5 per cent.) children found the yellow board was "plainer" or "showed up better."

[1] In the results are included data from a group of children aged about twelve, which was too small for inclusion in Table 4. These, counterbalanced by certain absentees in the repeated experiment, account for the slight increase in the total number.

[2] Not more than one reason is given for each child.

81 (19.3 per cent.) children found the blackboard was "plainer" or "showed up better."

28 (6.7 per cent.) children said the yellow board was less dazzling.

15 (3.6 per cent.) children said the blackboard was less dazzling.

9 (2.2 per cent.) children preferred the blackboard because they were accustomed to it.

6 (1.5 per cent.) children preferred the yellow board because it was "easier to find my place on it."

31 (7.5 per cent.) children preferred the yellow board because the "writing was (*i.e.* seemed) larger."

84 (19.5 per cent.) gave no reason.

Some individual opinions were interesting. Several found the yellow board "brighter"; two found that it was "easier to copy from". One said "I am used to black letters" (*i.e.* in book reading). One stated that the letters on the blackboard seemed to "jump about".

The most interesting comment was probably that of a boy who preferred the writing on the blackboard—"I find I can remember it more easily". This may possibly account for part of the reduction of effect of the yellow board on the second attempt. Children would tend, possibly, to remember better when faced with the blackboard because they are accustomed to remember things from it.

It seems doubtful whether any actual difference in the colours of the boards themselves would enable children to remember the writing on the blackboard more easily than that on the yellow.

X. SUMMARY AND CONCLUSIONS

The object of this research was to compare the time taken to read white letters on a blackboard and to copy them on to white paper with the time taken to read dark letters on a light-coloured board and to copy them on to white paper. Under the former conditions the eyes were subjected to repeated changes in brightness, whereas under the latter conditions the brightness of the board on which the words were presented and that of the paper on to which they were copied were nearly the same.

In the laboratory twenty-two adults were tested by a reaction-time apparatus and a voice-key, in order to compare their reading-times of short syllables according as they were written in white on a blackboard or in deep-blue on a yellow board. These times were on the average

15.4 per cent. quicker when the subjects read from the yellow board than when they read from the blackboard.

In three different experiments upon over 1,000 cases in elementary schools under classroom conditions, the speed of copying a set passage from a standard blackboard was compared with that of copying it from a yellow board. The children were found on the average to copy nearly 10 per cent. more in the same time from the yellow board than from the blackboard.

These results suggest that an appreciable saving in time, and presumably of strain, is obtainable by substituting a light yellow board for the standard blackboard.

NOTE

ON CERTAIN PRACTICAL CONSIDERATIONS

It is obvious that any advantage to be gained by employing a new type of board cannot be gained unless the board is easily obtainable at a reasonable price and of durable material.

The requirements of a school-room board are :—

(*a*) that it should be strongly constructed and stand the strain of wear for years ;

(*b*) that it should have sufficient 'tooth' to take the chalk easily ;

(*c*) that the chalk should wipe off, without undue rubbing, with a dry cloth. It is an added advantage if the board can be washed. In addition, it is essential that the chalk required should be easily obtainable.

As all these requirements are met by various blackboards at present on the market, the practical considerations involved in the introduction of a new board have necessarily received careful attention.

We are indebted to the Building Research Station, and the Paint Research Station of the Department of Scientific and Industrial Research, and the various manufacturers mentioned on page 7 for help in this part of the work. So far we have received samples of the following materials :

Cement for wall boards ;
Paint for wall or easel boards ;
Wall Cloth for wall or easel boards, or roller type boards ;
Glass (Painted) for wall boards or sash boards ;
Rubber (all types);
Faience (wall boards);
Enamelled Metal—(all types).

Certain of these materials have been tried without great success, and it seems probable that Glass, Wall Cloth (on a roller) and Faience may prove the most serviceable.

The darkest of the blue chalks already on the market is fairly satisfactory, but attempts are being made to produce one still darker. It is hoped also to provide the chalk with a greater glazing to prevent soiling the fingers.

Boards of all types made from one or other of the materials mentioned may be used, *e.g.* :

Wall boards
Easel boards

Roller boards

Sash boards

Frame boards (where a wooden board is held in a frame close to the wall at a slightly inclined angle).

It is not possible at the moment to lay down any recommendation as to which of these is the best. Choice will be dependent on the size of room, the position of windows and artificial light, the type of work done, and the disposition of the students. Cost is usually an important consideration also.

If there is no objection to using a moist duster, existing boards may be treated with several coats of primrose paint obtainable from blackboard paint manufacturers. The surface so produced is excellent in every respect except that the chalk cannot be removed with a dry cloth.

APPENDIX

ON CERTAIN THEORETICAL CONSIDERATIONS

THE experiments recorded in the present report cover a wide field, and the results have raised a number of interesting physiological and psychological considerations. Again, in the course of the work various points have become more clear, but nevertheless any account of it tends rather to follow the lines along which the investigator travelled. Thus, it may be objected that the assumption that adaptation is the cause of the differences in reading times and copying times is too great a one to be made—yet it was on this assumption that the investigation was first started. Other reasons may be put forward to account for the results, but such reasons do not nullify the main conclusion of the work—that it is probably advantageous to use dark blue chalk on a light coloured board in place of white chalk on the usual blackboard.

Some other factors which might be responsible for the facts observed may be mentioned. The first is the refraction of the eye when dealing with colours : the letters on yellow may look bigger because they are better focussed on the retina ; they may also be easier to focus and so may be read more quickly. The results of the Reversed experiment would, however, tend to suggest that this is not the sole, or indeed, the major, cause.

Secondly, the Gestalt psychologist will be tempted to say that the arguments advanced are based too much on the stimulus and response psychology, *i.e.* they assume that the only things that condition our perceptions are the colour, strength and duration of the sensory stimulus and the physiological condition of the sense organ. It will be realized, however, that in an experiment like the present one some such simplification is inevitable, and these further considerations arise naturally from the results obtained.

Thirdly, the use of a coloured board and of coloured (though, in effect, practically black) chalk may be criticised. Had the purpose of the investigation been purely one of laboratory experimentation, the more obvious comparison of black on white and white on black would have been made. In the circumstances, however, it seemed advisable not to spend too much time on theoretical points, but to proceed directly to the investigation of the particular apparatus which would probably be most satisfactory in practice.

It is unfortunate that the information available concerning the eyesight of the five subjects (in the laboratory Experiment) with refractive

defects is so scant. In any case their numbers are too small to warrant any deduction from their results ; further experiment on this point will be necessary.

Various objections may be raised to the section on Apparent Size (p. 21). The difference noted in apparent size may not be due to irradiation ; it may be that the phenomena are similar to those observed and explained by Gestalt psychologists. Thus, possibly, both here and as discussed above, the Gestalt point of view may be as important as that which considers only the conditions of the simple sensory stimulus.

That the laboratory and classroom experiments were designed to be complementary will already have become apparent to the reader. It is worth noting that the experimental conditions were very different in one respect—namely, in the background and surrounds of the apparatus. In the laboratory experiment, as explained, the apparatus was designed to occupy practically the whole visual field, and the lighting (which was from behind the subject) produced no appreciable glare or bright spots in that field. In the classroom, on the other hand, a large amount of the field of vision was occupied by objects other than the apparatus (the boards). In some rooms the walls were very light, in others fairly dark ; in some there was a considerable amount of dark furniture. But all such surrounds and background remained the same when the blackboard was substituted for the yellow (or vice versa). Thus, although the influence of such factors has not been measured, it may be considered constant.

On the subject of momentary adaptation (pp. 10 and 16) it is worth while to quote Hering (*Zur Lehre vom Lichtsinn*, in Gräfe-Sämisch's *Handbuch der gesamten Augenheilkunde*, Teil I, Kap. 12. Leipzig, 1905 and 1907, p. 17).

According to Hering, Aubert was the first to investigate more thoroughly the change in light sensitivity in proportion to illumination, and he called it adaptation. Hering called it successive or durative adaptation in contrast to the adaptation which is brought about by the interaction of the different retinal elements.

This interaction, said Hering, depends upon the fact that the stimulation in turn of each individual retinal element (*somatisches Sehfeldelement*) determines at the same time the light sensitivity of all the others: conversely the light sensitivity of the given element depends on the simultaneous stimulation of the remainder.

"Hence, when a retinal element is altered by the light this change affects, simultaneously and in proportion to the influence of the stimulus, the rest of the retina, and decreases its light sensitivity. In this way the light sensitivity of one element becomes a function of the total illumination of the retina and, in particular, the stronger this illumination becomes the weaker is the light sensitivity.

"This adaptation in light sensitivity which is conditioned by this interaction, takes place therefore almost at the same time as the change of illumination—that is why I have called it simultaneous or momentary adaptation. Durative adaptation on the other hand presupposes the continuation of weaker (or of stronger) illumination."

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